SYSTRA SWS

# UNDERGROUND EXPERIENCE

CONFIDENCE MOVES THE WORLD

# INTRODUCTION

SYSTRA SWS is an independent Engineering company with headquarters in Northern Italy, international profile (subsidiaries in Norway, Sweden, France, UK, Canada, USA, Algeria, Turkey) and more than 40 years of experience in Infrastructural and Tunneling design. The extensive experience in tunnel design and the strong efforts in R&D pushes SWS to cover a worldwide leadership in complex tunneling design infrastructure.

SYSTRA SWS Engineering is also the Designer of the Brenner Base Tunnel, the longest railway tunnel worldwide: 70 km main tunnel (180 km in total with service tunnels). The match between the 40 years' experience in complex tunneling design and the Digital transformation devised patented Digital Tools to support the tunnel's design solution.

The digitalization approach has the aim, on a cost-benefit optimized configuration, to achieve the best rate in terms of safety, sustainability and suitability features. This approach suits well to early stage tunnel's designs in complex conditions where a multi-parametric risk analysis is required to reach the best optimized solution.

For example projects in a feasibility study phase, where a lot of uncertainties shall be analyzed and solved. A multi-parametric risk analysis can be valuable to support the feasibility study as following:

- Choice of the "best" alignment based on risk assessment;
- Choice of the "optimized" construction methodology based on the comparison between mechanised (TBM) and traditional tunnel method (Drill&Blast/Cut&Cover);
- Cost-benefit optimized configuration.

Digital Project is the name given by SYSTRA SWS to the digitalization of civil infrastructures design processes. This approach permits to associate the conventional modelling to a computer aided design approaches such as: multi-objective optimizations, sensitivity analyses, statistical analysis, process optimization.

The CBA (Cost Benefit Analysis) is driven by a multi-parametric risk analysis that checks different solutions and selecting the best one in terms of less risk level. Thus, differently from conventional methods of calculation by representative sections, here the calculation process is automized and extended over the alignment, time-saving and standardizing results.

**Grand Paris Express**
**Line 15 lot T2A**
**FRANCE**

# SWS EXPERIENCE

In Italy and worldwide SYSTRA SWS is recognized leader in engineering and construction services within Tunnelling and Geotechnical works. SYSTRA SWS is committed to technical quality and deeply devoted to excellence & innovation.

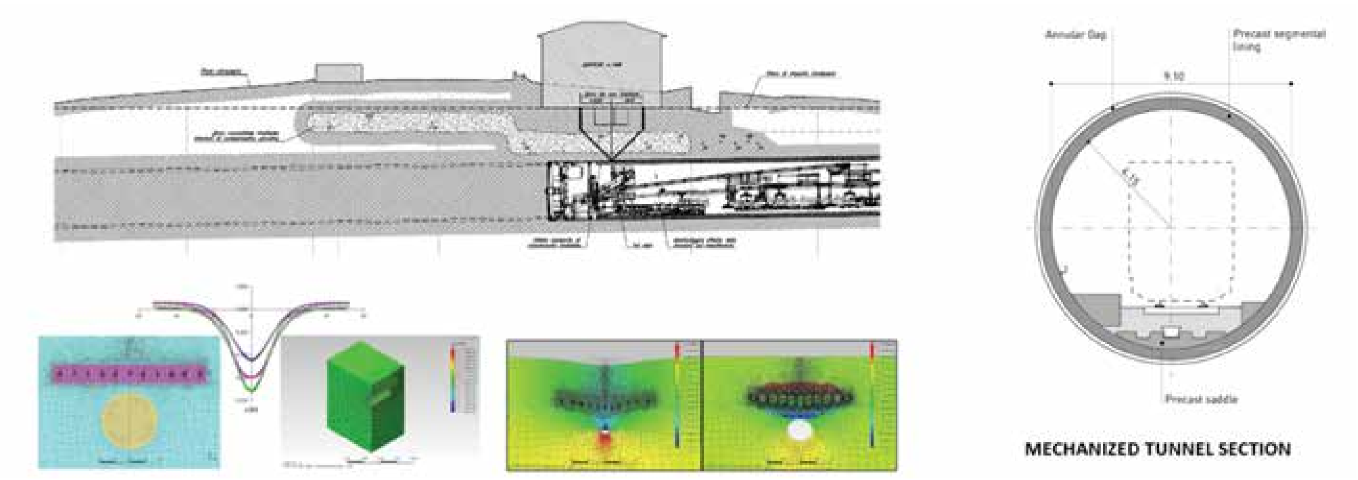
The Company is organised to provide effective solutions for every Client's requirement, assuring not only comprehensive, detailed and truthful information, but also confidentiality, flexibility, accuracy and punctuality.

## Metro and Railways

SYSTRA SWS is strongly committed to delivering a 360-degree design service for Mass Rapid Transit in urban areas. Our expertise covers different technical areas such as alignment and general design, structural and geotechnical design of tunnels and associated civil works, settlement analysis and monitoring.

Currently SYSTRA SWS is the main designer of the Brenner Base Tunnel, the longest rail tunnel worldwide. Most significant examples of tunnels in highly urbanized area are Paris metro and Florence railway link.

Our offices conceive innovative and reliable solutions for the most widely used rail transportation systems. SYSTRA SWS expertise in Conventional Rail Links, High-Speed Lines (HSL) and Light Rail Transit (LRT), covers alignment and general design, structural and geotechnical design of civil works, trackworks, signalling, earthworks and drainage, MEPs, environmental criteria.


*Florence railway link - Urbanized area*

Moreover, SYSTRA SWS is present in Norway since 2015 working on the Follo Line Project (Oslo S and Drill & Blast) as main civil designer for Bane NOR. In October 2019 SWS has awarded also the Nykirke-Barkåker project as leading designer of the JV Salini Impregilo-Pizzarotti.


**Florence railway link**
**High Speed Rail**
**ITALY**

# OUR TUNNELS

462+km
RAILWAYS

144+km
METRO

98+km
ROAD TUNNELS

28+km
HYDRO

## Mechanised Tunnels

Tunnels
732+km

Mechanised Tunnels
435+km

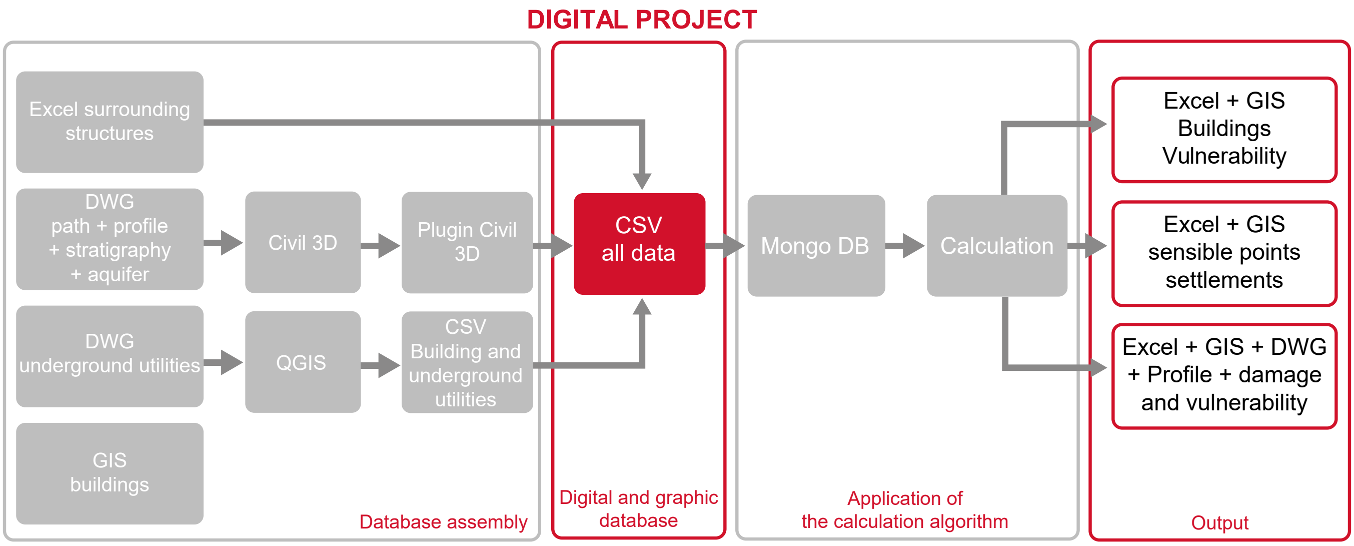
Conventional Tunnels
297+km

## MECHANISED TUNNELS

| TBM | EPB | SLURRY |
| --- | --- | --- |
| Open Mode TBM | Close Mode TBM EPB | Slurry |
| 345+km | 40+km | 50+km |

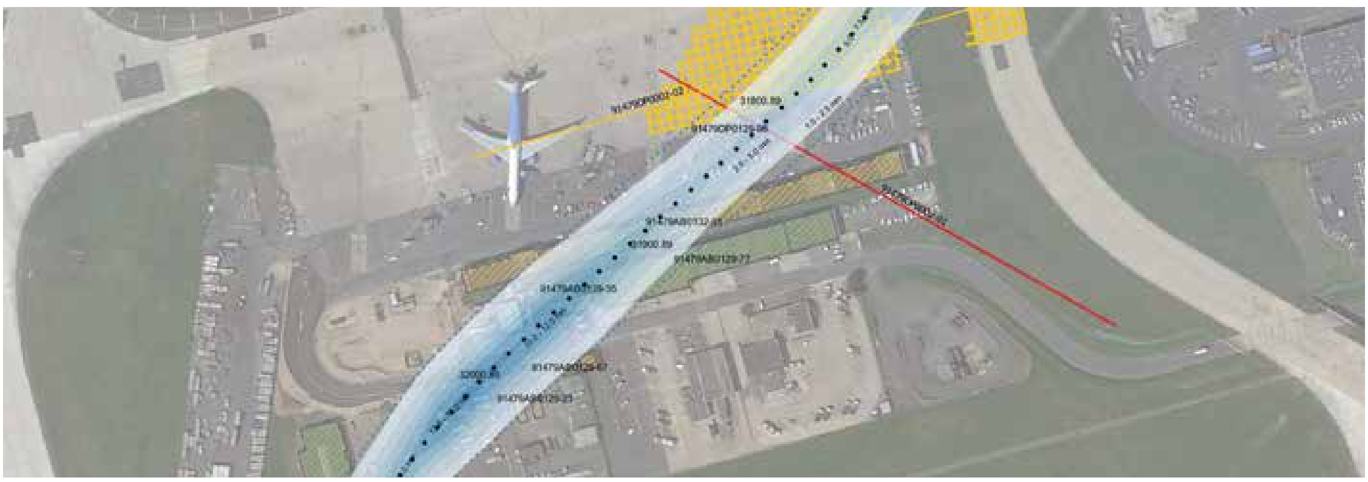
# DIGITAL PROJECT

Digital Project application in tunnels provides a set up tools and procedures able to support the Client in comparing the ability of different excavation method to cope with a series of risks sources pre-identified by the Client. The Digital Project application in tunnels performs a detailed and extensive investigation of the rock mass/soft soil response to chosen excavation method according to the Monte Carlo approach, and exploits the results to support Clients for risk analysis and TBM selection or comparison with traditional excavation method.




*Digital Project Operating Flowchart*

The main advantage of the Digital Project approach is to establish a robust methodology, as objective as possible, to be consistently applied to all available TBMs/excavation method, able to take into consideration project variability, and producing a simple scoring system where to consistently compare heterogeneous performances (e.g. geotechnical risk vs production rate).



*Digital Project Example of result visualitazion, Grand Paris Express metro*

## 1. INPUT

DIGITALISATION OF AVAILABLE DATA

- Location of the structure using Civil 3D
- Stratigraphy and geotechnical parameters
- Data related to surronding structures using Q-GIS

STRUCTURES DISCRETISATION

Digitalization, and geolocation of the structure and its surrounding structures using GIS, to associate it with project information, the sensibility of building N° XYZ, and the settlement and vibration thresholds.

*AUTODESK CIVIL 3D*

## 2. PROJECT DATABASET

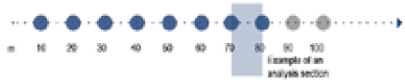
The input data are classified and organized in the form of a digital matrix in a database to be easily interrogated and then processed during the project analyses.

Sheet for each structure and network

*PDF QGIS*

## 3. PRESSURES COMPUTATION

FOR EACH SECTION OF ANLYSIS

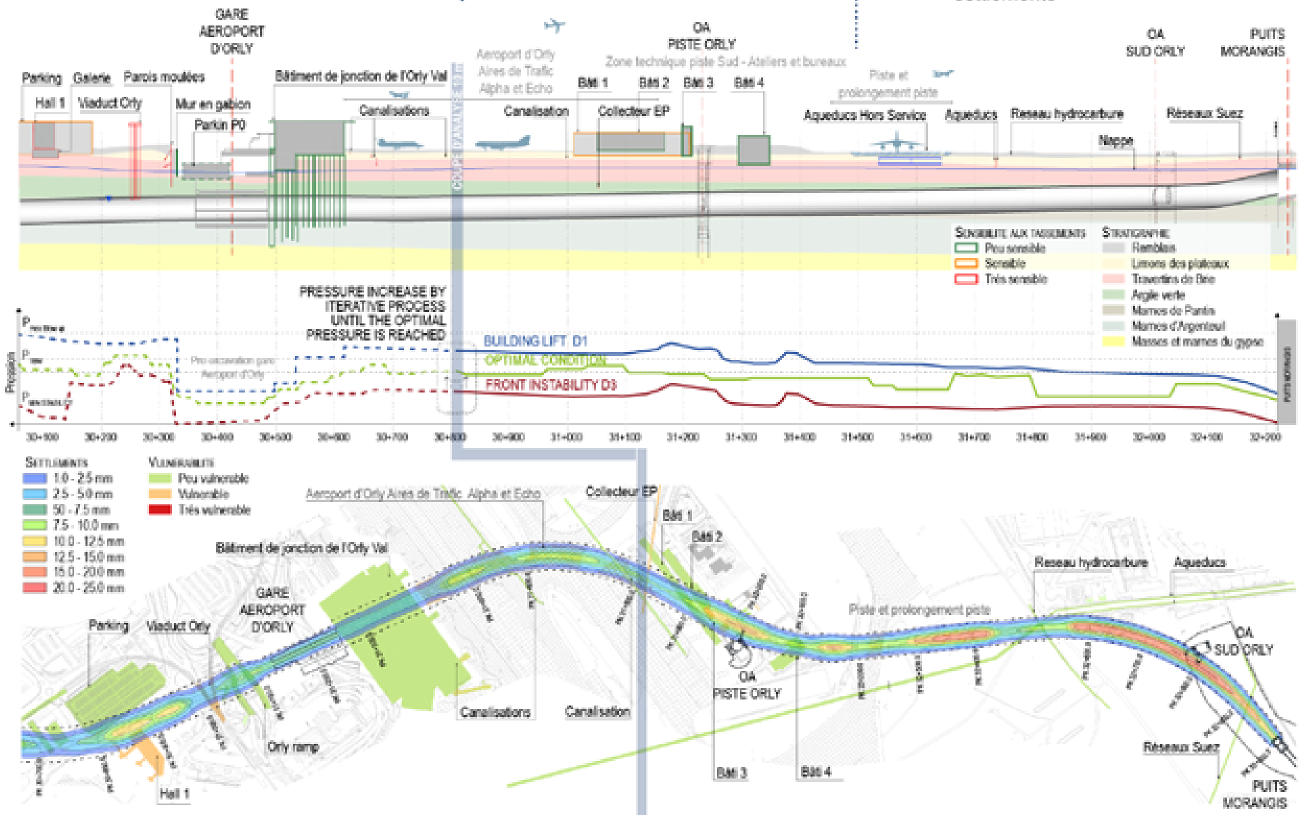



EVALUATION OF MINIMUM AND MAXIMUM PRESSURE VALUES

- Front stability (Minimum pressure)
- Blow-up (Maximum pressure)

AIM

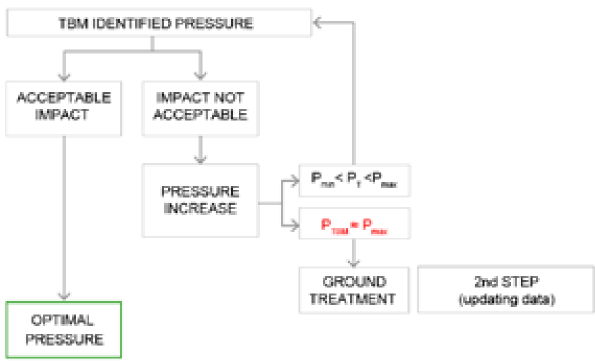
- Searching the optimal TBM pressure which also allows control of settlements




## 4. PROCESS ITERATION

ONCE IDENTIFIED THE TBM PRESSURE, EVALUATION OF:

- Loss of volume (function of pressure)
- Induced settlements and the vulnerability of the surrounding structures



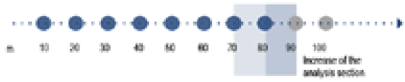


## 5. RESULTS REGISTER

The results are classified in terms of :

- Optimal TBM pressure
- Surrounding structures vulnerability class
- Subsidence curve and loss of volume

After the recording of the results of each section, we proceed to the analysis of the next section.




## 6. OUTPUT

- Pressure profile
- Map of iso-settlements and vulnerability of surrounding structures

# RISK ANALYSIS
# DIGITAL PROJECT

Based on Client requirements, a series of risk sources is identified. The resulting generalized risks events, considered relevant with the selection of the TBMs/excavation method, are usually grouped in three main risk families:

| ACTIVITY | Risk Families | Description |
|---|---|---|
| RISK IDENTIFICATION | Geotechnical (G) | Risk related to geological conditions |
| | Environmental (E) | Risk related to environment and landscaping |
| | Production (P) | Risk related to daily production/excavation process |
| | Other (V) | Other risks |

*Digital Project Risk Categories*

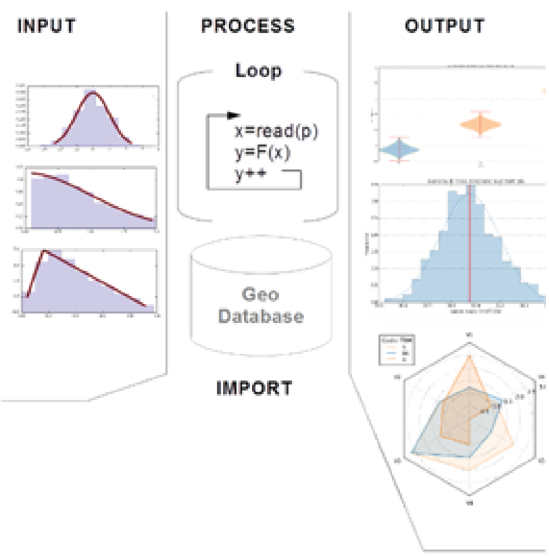
**Risk analysis process had two main targets:**

**1.** Select a "risk score" based on the impact of consequences and the likelihood of the + of each risk event. The risk score had to be dimensionless to be able to compare heterogeneous risk events.

**2.** Define, analytical geomechanical and mechanical model or statistical models able to define the likelihood of occurrence of an event, for a given TBM/excavation, at a given chainage and for a given set of geomechanical parameters.

| Risk matrix | | | | | |
|---|---|---|---|---|---|
| Likelihood | Possible | 4 | 8 | 12 | 16 |
| | Unlikely | 3 | 6 | 9 | 12 |
| | Highly Unlikely | 2 | 4 | 6 | 8 |
| | Improbable | 1 | 2 | 3 | 4 |
| | | Slight | Medium | Significant | Highly Significant |
| | | Consequences | | | |

*Digital Project Risk Matrix*




*Digital Project Risk Anlysis*

Risk evaluation is performed using a probabilistic-based method. This approach provides more realistic estimates using probability density functions for the input data instead of using fixed single values; for each parameter a probability density function is assigned.

Therefore during the analysis different solutions are checked and the chosen one is the best one in terms of less risk level and cost benefits.

Catania metro
Nesima-Misterbianco
ITALY

**SYSTRA SWS**

Via della Stazione 27
38123 Trento, Italy
Tel. +39 0461 979 000
sales@swsglobal.com

www.swsglobal.com